Burnt Corral
Vegetation Management Project

Carbon Cycling/Storage
And
Climate Change Write-up

Prepared By: David Vincelette, NKRD NEPA Planner

Prepared For: U.S.D.A. Forest Service, Region 3

Kaibab National Forest – North Kaibab Ranger District

Date: **DRAFT** – December 16, 2019

Printed on recycled paper – December 2019

Table of Contents

Introduction / Issues Addressed

This report describes the evidence and rationales why, in this case, additional analysis of this proposal's effects on "carbon storage potential", "greenhouse gas emissions", or "climate change" are not warranted under NEPA for a project of this size (i.e., less than 30,000 acres) and scope; however, a brief write-up is provided in response to climate change as a topic of public interest. "An issue is a statement of cause and effect linking environmental effects to actions" (Forest Service Handbook 1909.15).

Climate change is addressed throughout the Kaibab National Forest Land and Resource management Plan (USDA 2014, as amended), herein after referred to as the "Forest Plan;" the Forest Plan addresses the issue of "climate change" indirectly through desired conditions in the form of functional ecosystems and resilient landscapes, and directly in management approaches and the monitoring plan where appropriate. Appendix D to the Forest Plan titled "Kaibab National Forest's Climate Change Approach" provides a more detailed explanation of the strategy the Kaibab National Forest is utilizing regarding climate change or climatic change condition.

First, in order to understand or consider climate change, one must understand the definition of climate change. The Forest Plan (Forest Plan: pg. 157) defines Climate Change as follows:

> "Climate change refers to any significant change in the measures of climate lasting for an extended period of time. In other words, climate change includes major changes in temperature, precipitation, or wind patterns, among other effects, that occur over several decades or longer."

Climate change trending is generally measured in terms of changes over three decades (i.e., a 30-year or more time period) to potentially reflect what direction (i.e., up, down or somewhat constant) certain climate factors are headed or trending towards.

Methodology / Climate Change Considerations in National Environmental Policy Act Analysis

Climate change is one environmental effect that may be appropriate for managers of federal lands to consider when undertaking environmental analysis as part of the National Environmental Policy Act (NEPA) review process. In many ways, consideration of climate change is similar to the consideration of any other environmental effects. Considerations related to climate change include: 1. The effects of a project on climate change (through greenhouse gas emissions or carbon sequestration). 2. The effects of climate change on a proposed project. In other words, how climate change may influence the purpose and need for projects in the short-term (within the next 10 to 15 years) and long-term (over the next several decades); and 3. The implications of climate change for the environmental effects of a proposed action. These considerations may receive different levels of emphasis at different stages of the NEPA process and depending on the nature of a project and its potential effects.

The proposed action was developed to work towards Forest Plan desired conditions which were developed with climate change in mind. Appendix D to the Forest Plan recognizes that "climate

change exacerbates the already difficult task of managing the National Forest System for multiple goals" (Forest plan, pg. 205).

As part of its 2010 to 2015 strategic plan, the Forest Service launched a "Roadmap for Responding to Climate Change" (USDA 2010b). This comprehensive science-based plan emphasized a set of long- and short-term approaches for managing climate change while providing the agency with a clear, common vision. This strategic plan should help the Forest Service better provide for sustainability over time with climate uncertainty. The roadmap focuses on three primary activity areas: (1) assessing current risks, vulnerabilities, policies, and gaps in knowledge; (2) engaging internal and external partners in seeking solutions; and (3) managing for resilience in ecosystems as well as in human communities. A component of the strategic plan is a "Performance Scorecard" (http://www.fs.fed.us/climatechange/pdf/Scorecard.pdf), to be completed annually by each national forest or grassland. This scorecard has a series of questions focused on the above three activity areas that allow each management unit to assess how well integration of climate change considerations is happening at the local scale. The scorecard assesses agency capacity, partnerships and education, adaptation, mitigation, and sustainable consumption. The 2015-2020 strategic plan (USDA 2015) builds upon that initiative and explicitly identifies the following key climate related objective that should help to sustain the nation's forests and grasslands:

• Strategic Objective A: Foster resilient, adaptive ecosystems to mitigate climate change

Healthy ecosystems have the capacity for renewal, for recovery from a wide range of disturbances, and for retention of ecological resilience while meeting current and future needs. Continued investment in restoration work and managing the land will help ensure that forests and grasslands continue to deliver values, uses, products, and services that people want and need, such as clean air and water; high-quality recreation settings and opportunities; scenic character; forest products; cultural sites; and a full suite of habitats for plant, aquatic, and wildlife species (including threatened and endangered species). Working with our partners, the Forest Service's ecological restoration projects will support the growth and development of healthy ecosystems and vibrant, resilient communities.

The climate change roadmap directs national forests and grasslands to develop climate change vulnerability assessments and identifies monitoring strategies. In a recent draft Climate Vulnerability Assessment (CVA) developed for the Kaibab NF (USDA 2015), 37 % of the plan area is moderately vulnerable, 33 % is highly vulnerable and 29 % is very highly vulnerable to climate change. The report further describes vulnerability by ecosystem type, watershed unit and ranger district across the forest. Within the tree-shrub component, frequent fire mixed conifer, ponderosa pine and pinyon juniper grassland are all moderately to highly departed from reference conditions with both high resistance to, and resilience from disturbance events. Riparian systems, spruce fir forest and mixed conifer with aspen have low resistance to disturbance but are expected to be moderately to highly resilient to these events once they have occurred. Within in the herbaceous component of these systems, the majority of the forest is moderately departed with low resistance to disturbance, and moderate to high resilience from disturbance. These measures of resistance and resilience are important complementary concepts that can help to guide climate smart conservation strategies on the Kaibab NF. Nimmo et al.

(2015), note that by adopting a 'resistance–resilience' framework, important insights for conservation can be gained such as determining what specific characteristics certain ecological systems have that are associated with both resilience and resistance. While 'resistance' is the ability to persist during the disturbance, 'resilience' is the capacity to recover or 'bounce back' following alleviation of the disturbance. Systems with low resistance and resilience are most at risk, while systems with high resistance and high resilience. Considering these factors along with other resource values can be an important strategy in prioritizing management action.

The Forest Service's 2010 to 2015 strategic plan goes on to list several means and strategies for achieving this objective which include: Coordinate inventory, monitoring, and assessment activities across all lands to improve our adaptive management of natural resources. The Kaibab National Forest is actively engaging with its partners in the development, application and monitoring related to modeling. The following website was developed and is dedicated to spatially explicit models of occupancy for evaluating forest restoration and climate change on the Kaibab National Forest, Arizona. Link:
https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5380372.pdf

Such partnerships and sharing of resources helps to leverage capacity and improve monitoring efficiencies that will better monitor the interactive effects of management and climate related change.

Projects like Burnt Corral are designed to restore the health, resilience and productivity of forested ecosystems would improve the ability of the landscape to endure climate change stresses. Thinning reduces competition between trees for light, moisture and nutrients improving tree vigor. The remaining trees would be more able to survive wildfire, disease and insect attacks when stressed by drought. Implementation of the Burnt Corral project will help increase resilience (of forested areas within the project) to changes brought on by wildfire and a warming climate. Healthy, green forests produce many ecosystem services, especially the storage of atmospheric carbon (USFS, 2015; Malmsheimer et al, 2011).

"*Managing America's forests and grasslands to adapt to changing climates will help ensure that they continue to produce the benefits that Americans need, while helping to mitigate the effects of a changing climate and to compensate for fossil fuel emissions through carbon storage in healthy forests.*" (USDA, Office of the Chief, 2015)

Carbon Cycling and Storage

The importance of carbon storage capacity of the world's forests is tied to their role globally in removing atmospheric carbon that is contributing to ongoing global warming. As discussed further below, meaningful and relevant conclusions on the effects of a relatively minor land management action such as this on global greenhouse gas emissions or global climate change is neither possible nor warranted in this case.[1] Nevertheless, we recognize that global research indicates the world's climate is warming (Flannigan and others 2000, Seager and Vecchi 2010)

[1] While huge advances have been made in accounting and documenting the relationship between greenhouse gases and global climate change, difficulties remain in reliably simulating and attributing observed temperature changes to natural or human causes *at smaller than continental scales* (IPCC 2007, p. 72).

and that most of the observed 20th century increase in global average temperatures is very likely due to increased human-caused greenhouse gas emissions.

Forests are dynamic systems that naturally undergo fluctuations in carbon storage and emissions as they establish and grow, die through natural aging, competition processes or disturbances (e.g. fires, insects), and re-establish and regrow. They are in a continual flux, both emitting carbon into the atmosphere and removing it (sequestration) through photosynthesis. When trees and other vegetation die, carbon is transferred from living carbon pools to dead pools, which release carbon dioxide through decomposition. Fires also release carbon dioxide directly to the atmosphere through combustion. See project file documents 20190604CarbonNFG and USFSCargonInfographic (no date). The long-term capacity of forest ecosystems to absorb and sequester carbon depends in large part on their health, productivity, resilience, and ability to adapt to changing conditions.

The proposed action would likely influence the rates and timing of carbon release and sequestration within individually affected forest stands. These changes would be localized and infinitesimal in relation to the role the world's forests play in ameliorating climate change, and indistinguishable from the effects of not taking the action. While the proposed prescribed burning would release carbon through smoke emissions, a net gain of sequestered carbon is expected due to the combination of increased understory production, increased diameter growth of the remaining released trees, and protection of the larger, older trees. Continental and global factors related to forest's influence on global climate change are briefly discussed to provide context for understanding the nature of these local effects.

Efficacy of the Proposed Action in Light of Climate Change

The proposed action has several desired outcomes. The effectiveness of achieving those outcomes is presented throughout the EA and underlying analysis (keeping in mind that NEPA requires an agency to take a hard look at the consequences of its actions on the environment, not the other way around). The interdisciplinary team considered the existing conditions and trends within the area, as well as risks, in designing this proposal to achieve those outcomes.

Global climatic change is not something that is about to happen. It has been ongoing for many decades and the trend is expected to continue into the distant future, continuing to increase risks to our nation's forests, and especially those in the Southwestern U. S. (Dale, et al. 2001; Barton 2002; Breashears and Allen 2002; Seager and others 2007, Westerling and Bryant 2008; Running 2006; Littell, et al. 2009; Boisvenue and Running 2010, Seager and Vecchi 2010, Hicke and others 2012). The existing project area conditions and trends are an expression of the local climate, which may or may not parallel ongoing continental or global trends, as it has interacted with the other local natural and anthropomorphic influences. As such, the ongoing effects of climate change were considered and integrated into the forest plan development, and the project was designed according to recommendations in the forest plan.

The proposed action addresses site-specific forest resilience trends and risks that exist within the project area today. The proposed action are consistent with adaptation actions and strategies recommended for managing forests in light of climate change in the forest plan (Forest Plan

Appendix D) and in other works (KPERP EA Development of Proposed Action; Millar and others 2007; Joyce and others 2008; Ryan and others 2008a; Hurteau and others 2014; Thorne and others 2018).

Other Contextual Considerations

Other factors also indicate that, in this case, further analysis is not necessary or warranted.

The top three anthropogenic (human-caused) contributors to greenhouse gas emissions (from 1970-2004) are: fossil fuel combustion, deforestation, and agriculture (IPCC 2007, p. 36). Land use change, primarily the conversion of forests to other land uses (deforestation, meaning the land no longer has trees), is the second leading source of human-caused greenhouse gas emissions globally (Denman, et al. 2007, p. 512). Loss of tropical forests of South America, Africa, and Southeast Asia is the largest source of land-use change emissions (Denman, et al. 2007, p. 518; Houghton 2005).

Unlike other forest regions that are a net source of carbon to the atmosphere, U.S. forests are a strong net carbon sink, absorbing more carbon than they emit (Houghton 2003; US EPA 2013; Heath, et al. 2011). Our National Forests accounted for approximately 24% of that net annual sequestration. Within the U.S., land use conversion from forest to other uses (primarily for development or agriculture) are identified as the primary human activities exerting negative pressure on the carbon sink that currently exists in this country's forests (McKinley, et al. 2011; Ryan, et al. 2010; Conant, et al. 2007).

This proposal does not fall within, and is distinguishable from, any of these primary contributors of global greenhouse gas emissions, nor is it similar to the primary human activities exerting negative pressure on the carbon sink that currently exists in U.S. forests, namely land use conversion. The affected forests will remain forests and the proposed action is expected to make them more resilient so that the long-term benefits will be maintained. They will not be converted to other land uses,

Environmental Consequences

The existing sources of greenhouse gas emissions associated with the proposed Burnt Corral Vegetation Management Project would be from fire (Rx Fire or managed wildfire), timber harvesting activities, transportation and mill processing activities, and distribution activities of final mill product. Some activities may seem to generate or release carbon which would not happen under the no action alternative, but consideration should be given to the fact that if a wood product (which is in demand and processed or milled through the proposed action at a local mill) not created through the no action alternative, would still be created or be supplied by another source (i.e., and outside or foreign supplier, not a local mill). Thus the no action alternative does not alleviate the demand for the wood product or curtail the production of the wood product from another part of the world. In other words, certain wood products that may be produced through the activities of this vegetation management project will still be in demand and have to be produced somewhere, whether this project is implemented or not. This approach or assumption was utilized in drafting or creating this write-up regarding climate change.

No Action Alternative

Direct and Indirect Effects

There would be no direct human-induced emissions of carbon into the atmosphere under the No-Action Alternative. The areas within the Burnt Corral project that are proposed for treatment would likely continue to function as carbon sinks until the next disturbance event (e.g., fire, wind, insect infestation, etc.) occurs. When the next stand-replacing disturbance event (i.e., high tree mortality) occurs, the affected areas would convert to a carbon source condition (i.e., emitting more carbon than is being sequestered). This state would continue for up to a decade or more until the rate of regrowth meets and exceeds the rate of decomposition. As stands continue to develop, the strength of the carbon sink would increase, typically peaking at an intermediate age and then gradually declining, but remaining positive (Pregitzer and Euskirchen 2004). Carbon stocks would continue to accumulate, although at a declining rate, until again impacted by subsequent disturbance.

The risk of some high-mortality disturbance events is greater under the no-action alternative. The long-term ability of these areas to persist as a net carbon sink is uncertain (Galik and Jackson 2009). Drought stress, wildfires, insect outbreaks and other disturbances may substantially reduce existing carbon stock (Galik and Jackson 2009, Hicke et al 2012). Climate change threatens to amplify risks to carbon stocks by increasing the frequency, size, and severity of these disturbances (Dale, et al. 2001; Barton 2002; Breashears and Allen 2002; Westerling and Bryant 2008; Running 2006; Littell, et al. 2009; Boisvenue and Running 2010). Increases in the severity of disturbances, combined with projected climatic changes, may limit post-disturbance forest regeneration, shift forests to non-forested vegetation, and possibly convert large areas from an existing carbon sink to a carbon source (Barton 2002; Savage and Mast 2005; Allen 2007; Strom and Fulé 2007; Kurz, et al. 2008a; Kurz, et al. 2008b; Galik and Jackson 2009). Leaving areas of forest densely stocked, as in the no-action alternative, maintains an elevated risk of carbon loss due to disturbance. Prescribed fire and other management actions are often suggested as climate change “adaptation actions” because they may increase forest resilience to these multiple stresses, and thus increase the likelihood of sustaining forest carbon benefits in the long-term (Millar, et al. 2007; Joyce, et al. 2008; Ryan, et al. 2008b). The no-action alternative foregoes such climate change adaptation actions.

Proposed action

Direct and indirect effects of the proposed action

In the short term, the proposed action would remove and release some carbon currently stored within treatment area biomass, through cutting vegetation and prescribed fire. Due to a timber-to-lumber component, some carbon stock would be locked up in products created or generated at the mill that is producing wood products from the processing of raw timber. However, the activity of processing of that raw timber (i.e., the harvesting, transport, and milling) would in itself, also produce some carbon that would be released into the system through greenhouse gas emissions.

According to Forest Vegetation Simulation (FVS) modeling completed as part of the Silvicultural Assessment (Domis 2019):

> "The indirect effects of thinning and burning include improved forest health. Due to lower basal area and SDI and less competition, there would be more sunlight, moisture, and nutrients available to residual trees. Also, the remaining trees would have higher base heights and torching indexes for greater fire resistance, and better potential for ground fire. There would also be greater resilience to insect attack.
>
> The better the host vigor, the greater tree defense to kill beetles by drowning or immobilization in resin when adequate moisture, oleoresin flow, and exudation pressure exists. Stressed trees (from drought, fire, inter-tree competition, or disease) are susceptible to attack, especially by *Ips* and *Dendroctonus* species. When individual trees have sufficient resources (light, nutrients, moisture), vigorous individuals are more likely to fend off beetle attacks (DeGomez et al, 2008). The proposed thinning treatments would improve tree health and resistance to disturbance such as bark beetle colonization."

For at least the short term, on-site carbon stocks would be lower under the proposed action than with no action. However, the long-term potential to lock up more carbon would be increased due to the fact that tree growth would be more robust, this is due to less competition of resources amongst the remaining trees versus the higher tree density of pre-treatment conditions (i.e., water, sunshine, soil nutrients, etc.) (Myhre 2019).

The proposed mechanical treatments and prescribed fire treatments would reduce existing carbon stocks and temporarily reduce net carbon sequestration rates within treated stands in some areas, possibly enough that for the short term the stands would emit more carbon than they are sequestering. These stands would remain a source of carbon to the atmosphere (or weakened sink) until carbon uptake by new and remaining vegetation again exceeds the emissions from decomposing dead organic material. As stands continue to develop, the strength of the carbon sink would increase then gradually decline, but remain positive (Pregitzer and Euskirchen 2004). Carbon stocks would continue to accumulate, although at a declining rate, until impacted by future disturbances.

The risk of some high-mortality disturbance events is greater under the no-action alternative. To the extent the proposed action reduces the risk or delay future stand-replacing disturbance events; potential emissions from those events would be reduced or forestalled.

Research has shown that the long-term gains acquired through prescribed fire and mechanical thinning outweigh short-term losses in sequestered carbon (Forest Plan Appendix D, p. 213). In the long term (e.g., 100 years), thinning and burning would create more resilient forests that sequester carbon at higher rates and are less prone to stand-replacing events, and subsequently able to store more carbon in the form of large trees. Additionally, prescribed burning and mechanical thinning would result in more open conditions conducive to understory production, particularly perennial grasses, which store subsurface carbon (Moore and Deiter 1992).

The long-term ability of forests to sequester carbon depends in part on their resilience to multiple stresses, including increasing probability of drought stress, high severity fires, and large-scale insect outbreaks associated with projected climate change. Management actions, such as those proposed with this project that move the area toward desired conditions can maintain the capacity of the forest to sequester carbon in the long-term. Thus, even though some management actions may in the near-term reduce total carbon stored below current levels, in the long-term they maintain the overall capacity of these stands to sequester carbon, while also contributing other multiple-use goods and services (Reinhardt and Holsinger 2010).

Forest Restoration Efforts: Climate change, catastrophic wildfire, bark beetle infestation, invasive species, record droughts, and other stressors threaten the health of our forest and watersheds, and the people that rely on them. Through collaboration with stakeholders and other interested parties, the Forest Service is working hard to increase the rate of restoration in the face of these mounting challenges. Collaborating or working with other stakeholders on landscape scale restoration projects, such as Burnt Corral, will help restore the ecological integrity of the west-side ponderosa pine belt on the NKRD, where the forested areas need to be healthy, now and into the future.

Cumulative effects of the proposed action

None of the alternatives affect climate change to any measurable level. The no action alternative has the highest potential to release carbon in a relatively large quantity over a short period of time due to the increased risk of a stand-replacing wildfire occurrence. Carbon will still continue to be stored under the no action alternative but at a slower rate than the action alternatives. The proposed action will increase tree growth more than the no action alternative and will sequester more carbon, the proposed action will make the forest most resilient to climate change because it will have the lowest density of trees.

The proposed action would have no discernable impact on atmospheric concentrations of greenhouse gases or global warming, considering the limited changes in both rate and timing of carbon flux predicted within the affected forest acres treated over the next 20 years or so, the global scale of the atmospheric greenhouse gas pool, and the multitude of natural events and human activities globally contributing to that pool.

Although not a statutorily defined purpose of National Forest System management, forests do provide a valuable ecosystem service by removing carbon from the atmosphere and storing it in biomass (Galik and Jackson 2009) or products created from harvested timber. U.S. forests are a strong net carbon sink, absorbing more carbon than they emit (Houghton 2003; US EPA 2013; Heath, et al. 2011). For the period 2000 to 2008, U.S. forests sequestered (removed from the atmosphere, net) approximately 481.1 Tg of carbon dioxide per year, with harvested wood products sequestering an additional 101 Tg per year. Our National Forests accounted for approximately 30% of that net annual sequestration. National Forests contribute approximately 3 Tg carbon dioxide to the total stored in harvested wood products, compared to about 92 Tg from harvest on private lands (Heath, et al. 2011).

Within the U.S., land use conversions from forest to other uses, primarily for land development or agriculture, are identified as the primary human activities exerting negative pressure on the

carbon sink that currently exists in this country's forests (McKinley, et al. 2011; Ryan, et al. 2010; Conant, et al. 2007). The affected lands in this proposal would not be converted to other land uses. Long-term ecosystem services and benefits would be maintained.

Consistency with Relevant Laws, Regulations, and Policy

Regulatory Direction

There are no applicable legal or regulatory requirements or established thresholds concerning management of forest carbon or greenhouse gas emissions. NEPA applies to "major Federal actions," and the NEPA process begins when a Federal agency develops a proposal to take action. NEPA requires that agencies consider significant effects of proposed actions on the human environment in our decisions. The purpose of an environmental assessment is, in part, to determine whether there may be significant effects that warrant the preparation of an environmental impact statement (40 CFR 1508.9).

Land and Resource Management Plan

Attachment B to the Proposed Action, as scoped in March of 2015, included the relevant selections from the Forest Plan, as they relate to desired conditions and the management approach of various vegetation types (i.e., Ponderosa Pine, Aspen, and all vegetation types). The applicable standards and guidelines from vegetation types were evaluated and considered in the development of the proposed action for the project. Appendix B to the proposed action also lists other relevant laws, rules, and regulations that may be applicable to the Burnt Corral Vegetation Management Project.

Each resource area has looked at the applicable requirements when they evaluate their specific resource area and perform in-depth analysis during NEPA to identify any relevant sections of the Forest Plan, as it relates to the proposed action.

Forest Plan Link: http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprd3791580.pdf

Guidance on Consideration of Climate Change in Project-related NEPA

Council on Environmental Quality

Council on Environmental Quality (CEQ) guidance was rescinded; Executive Order 2017-06576 rescinded the CEQ final guidance entitled ''Final Guidance for Federal Departments and Agencies on Consideration of Greenhouse Gas Emissions and the Effects of Climate Change in National Environmental Policy Act Reviews,'' which is referred to in ''Notice of Availability,'' 81 Fed. Reg. 51866 (August 5, 2016).

Forest Service

The Forest Service has prepared agency guidance on "Climate Change Considerations in Project Level NEPA Analysis" (http://www.fs.fed.us/emc/nepa/climate_change/index.htm). Similar to the previous CEQ guidance this document focuses on the dual aspects of climate change: 1) the effect of a proposed project on climate change through greenhouse gas emissions, and 2) the

effect of climate change on a proposed project. The guidance stresses considerations in Pre-NEPA analyses, including the purpose and need and proposed action, scoping, alternative development, effects analysis, and decision documents. *The focus of the guidance is to incorporate climate change into project NEPA that is relevant for the project decision*. The Forest Service will revise this guidance as scientific understanding improves, climate change management experience is gained, and national policies are revised.

FS Climate Change Resource Center: The Forest Service has many tools and information regarding Climate Change; one such tool is the Climate Change Resource Center website: https://www.fs.usda.gov/ccrc/. This website offers a plethora of information pertaining to education, various climate change topics, climate change and carbon tool kits, adaption (featured stories, examples, and research), and a vast library of information which includes over 2,300 publications.

Forest Products Modernization: Forests across the nation are facing serious challenges. Insects, disease, drought, and wildfire all threaten forest health and productivity. There are an estimated 65 to 82 million acres of forest and grassland in need of restoration to lower fire risk and insect and disease impacts. Forest products modernization is a strategic effort designed to better align our culture, policies, and procedures with current and future forest restoration needs to increase the pace and scale of restoration, improve forest conditions, and improve efficiency of forest product delivery.

Conclusion section

Climate change is addressed as an integral part of the Forest Plan rather than as a standalone set of desired conditions. An example is the desired condition that "The composition, structure, and function of vegetative conditions are resilient to the frequency, extent, and severity of disturbances and components that provide resilience to climate variability." Integration of climate-relevant desired conditions throughout the Forest Plan helps to ensure these concepts are considered during project-level planning, such as the Burnt Corral project.

The Burnt Corral Vegetation Management Project would affect an insignificant amount of the total forest carbon stock within KNF-NKRD, however small, the effect is still expected to be in a positive direction. Thinning activities (mechanical and Rx fire) should lower the overall vulnerability by reducing the risk of catastrophic disturbances, and by improving the capacity for the forest to adapt (i.e., increase forest health and vigor, and reduce competition amongst trees for resources) to climate change, and facilitate the re-alignment of vulnerable areas (Triepke, et al. 2019).

References (Literature Cited)

Domis, Garry (NKRD Certified Silviculturist). Winter/Spring 2016. Burnt Corral Vegetation Management Project Environmental Analysis, Vegetation Resources Specialist Report, Kaibab National Forest - North Kaibab Ranger District, 59 p.

Malmsheimer, R.W., J.L. Bowyer, J.S. Fried, E. Gee, R.L. Izlar, R.A. Miner, I.A. Munn, E. Oneil, and W.C. Stewart. 2011. Managing Forests because Carbon Matters: Integrating Energy, Products, and Land Management Policy. Journal of Forestry 109(7S):S7–S50.

Myhre, L. (US FS Enterprise Program, Environmental Coordinator) June 2019. Kaibab Plateau Ecological Restoration Project, Carbon Cycling/Storage and Climate Change Report. 10p.

Triepke, F. J., E. H. Muldavin, and M. M. Wahlberg. 2019. Using climate projections to assess ecosystem vulnerability at scales relevant to managers. Ecosphere 10(9):e02854. 10.1002/ecs2.2854

USDA Forest Service, Southwestern Region. 2010a. "Southwestern Climate Change Trends and Forest Planning: A Guide for Addressing Climate Change in Forest Plan Revisions for Southwestern National Forests and National Grasslands."

USDA Forest Service. GTR-NRS-87 2010b. National Roadmap for Responding to Climate Change. 30 p.

USDA 2012. Forest adaptation resources: Climate change tools and approaches for land managers. Swanston, Chris; Janowiak, Maria, eds. GTR-NRS-87. 121 p.

USDA Forest Service. 2015. *Baseline Estimates of Carbon Stocks in Forests and Harvested Wood Products for National Forest System Units*. Southwestern Region. 41 pp.

USDA Forest Service 2015. USDA Forest Service Strategic Plan: FY 2015-20. FS--1045 June 2015. 60 p.

Allen, C.D. 2007. Interactions across spatial scales among forest dieback, fire, and erosion in northern New Mexico. Ecosystems 10: 797-808.

Barton, A. M. 2002. Intense wildfire in southeastern Arizona: transformation of a Madrean oak-pine forest to oak woodland. Forest Ecology and Management 165: 205-212.

Boisvenue, C. and S.W. Running. 2010. Simulations show decreasing carbon stocks and potential for carbon emissions in Rocky Mountain forests over the next century. Ecological Applications 20(5): 13-2-1319.

Breashears, D.D., and C.D. Allen. 2002. The importance of rapid, disturbance-induced losses in carbon management and sequestration. Global Ecology and Biogeography 11:1-5.

Conant, R.T., K. Paustian, F. García-Oliva, H.H. Janzen, V.J. Jaramillo, D.E. Johnson, S.N. Kulshreshtha. 2007. Chapter 10 Agricultural and Grazing Lands. In: CCSP, 2007. *The First State of the Carbon Cycle Report (SOCCR): The North American Carbon Budget and Implications for the Global Carbon Cycle.* A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research [King, A.W., L. Dilling, G.P. Zimmerman, D.M. Fairman, R.A. Houghton, G. Marland, A.Z. Rose, and T.J. Wilbanks (eds.)]. National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, NC, USA, 242 pp. http://www.globalchange.gov/publications/reports/scientific-assessments/saps/sap2-2

Dale, V.H, L.A. Joyce, S. McNulty, R.P. Neilson, M.P. Ayres, M.D. Flannigan, P.J. Hanson, L.C. Irland, A.E. Lugo, C.J. Peterson, D. Simberloff, F.J. Swanson, B.J. Stocks, and B.M. Wotton. 2001. Climate change and forest disturbances. BioScience 51:723–734.

Denman, K.L., G. Brasseur, A. Chidthaisong, P. Ciais, P.M. Cox, R.E. Dickinson, D. Hauglustaine, C. Heinze, E. Holland, D. Jacob, U. Lohmann, S. Ramachandran, P.L. da Silva Dias, S.C. Wofsy and X. Zhang. 2007. Couplings Between Changes in the Climate System and Biogeochemistry. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Depro, B.M., B.C. Murray, R.J. Alig, and A. Shanks. 2008. Public land, timber harvests, and climate mitigation: Quantifying carbon sequestration potential on U.S. public timberlands. Forest Ecology and Management 255 (2008) 1122–1134.

Finkral, A.J. and A.M. Evans. 2008. Effects of a thinning treatment on carbon stocks in a northern Arizona ponderosa pine forest. Forest Ecology and Management 255: 2743-2750.

Flannigan, M.D., B.J. Stocks, and B.M. Wotton. 2000. Climate change and forest fires. The Science of the Total Environment 262: 221-29.

Galik, C.S. and R.B. Jackson. 2009. Risks to forest carbon offset projects in a changing climate. Forest Ecology and Management 257 (2009) 2209–2216.

Gan, J. and B.A. McCarl. 2007. Measuring transnational leakage of forest conservation, Ecological Economics 64 (2007), pp. 423–432.

Harmon, Mark E. 2009. Testimony before the Subcommittee on National Parks, Forests, and Public Lands of the Committee of Natural Resources for an oversight hearing on "The Role of Federal Lands in Combating Climate Change", March 3, 2009. Includes attachments.

Heath, L.S., J.E. Smith, C.W. Woodall, D.L. Azuma, and K.L. Waddell. 2011. Carbon stocks on forestland of the United States, with emphasis on USDA Forest Service ownership. Ecosphere 2(1):art6 doi:10.1890/ES10-00126.

Hicke, Jeffery A., Craig D. Allen, Ankur R. Desai, Michael C. Dietze, Ronald J. Hall, Edward H (Ted) Hogg, Daniel M. Kashiam, David Moore, Kenneth F. Raffa, Rona N. Sturrock, and James Vogelmann. 2012. Effects of biotic disturbances on forest carbon cycling in the United States and Canada. Global Change Biology (2012) 18, 7-34, doi: 10.1111/j.1365-2496.2011.02543x

Houghton, R.A. 2003. Revised estimates of the annual net flux of carbon to the atmosphere from changes in land use and land management 1850-2000. Tellus B: 378-390.

Houghton, R.A. 2005. Aboveground forest biomass and the global carbon balance. Global Change Biology 11: 945-958.

Hurteau, M., et al. 2014. Climate change, fire management, and ecological services in the southwestern US. Forest Ecology and Management 327:280-289.

IPCC. 2007. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp.

Joyce, L.A., G.M. Blate, J.S. Littell, S.G. McNulty, C.I. Millar, S.C. Moser, R.P. Neilson, K. O'Halloran, and D.L. Peterson. 2008. National Forests. In: *Preliminary review of adaptation options for climate-sensitive ecosystems and resources.* A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research [Julius, S.H., J.M. West (eds.), J.S. Baron, B. Griffith, L.A. Joyce, P. Kareiva, B.D. Keller, M.A. Palmer, C.H. Peterson, and J.M. Scott (Authors)]. U.S. Environmental Protection Agency, Washington, DC, USA, pp. 3-1 to 3-127. Available online at: http://downloads.climatescience.gov/sap/sap4-4/sap4-4-final-report-Ch3-Forests.pdf

Kashian, D.M., W.H. Romme, D.B. Tinker, M.G. Turner, and M.G. Ryan. 2006. Carbon storage on landscapes with stand-replacing fires. BioScience 56: 598-606.

Kurz, W.A., C.C. Dymond, G. Stinson, G.J. Rampley, E.T. Neilson, A.L. Carroll, T. Ebata, and L. Safranyik. 2008a. Mountain pine beetle and forest carbon feedback to climate change. Nature 452: 987-990.

Kurz, W.A., G. Stinson, G.J. Rampley, C.C. Dymond, and E.T. Neilson. 2008b. Risk of natural disturbances makes future contributions of Canada's forest to the global carbon cycle highly uncertain. Proceedings of the National Academy of Sciences of the United States of America 105: 1551-1555.

Littell, J.S., D. McKenzie, D.L. Peterson, and A.L. Westerling. 2009. Climate and wildfire area burned in western U.S. ecoprovinces, 1916-2003. Ecological Applications 19: 1003-1021.

McKinley, D.C., M.G. Ryan, R.A. Birdsey, C.P. Giardina, M.E. Harmon, L.S. Heath, R.A. Houghton, R.B. Jackson, J.F. Morrison, B.C. Murray, D.E. Pataki, and K.E. Skog. 2011. A synthesis of current knowledge on forests and carbon storage in the United States. In press. Ecological Applications.

Millar, Constance I., Nathan L. Stephenson, and Scott L. Stephens. 2007. Climate Change and Forests of the Future: Managing in the Face of Uncertainty. Ecological Applications: Vol. 17, No. 8, pp. 2145-2151.

Moore, M.M., D.A. Deiter. Stand density index as a predictor of forage production in northern Arizona ponderosa pine forests J. Range Mgmt., 45 (1992), pp. 267-271.

Murray, B.C. 2008. Leakage from an avoided deforestation compensation policy: Concepts, empirical evidence, and corrective policy options. Nicholas Institute for Environmental Policy Solutions, Duke University, Durham, NC. 32p.

North, M., M. Hurteau, and J. Innes. 2009. Fire suppression and fuels treatment effects on mixed-conifer carbon stocks and emissions. Ecological Applications, 19(6), 2009, pp. 1385–1396.

Pregitzer, K.S. and E.S. Euskirchen. 2004. Carbon cycling and storage in world forests: biome patterns related to forest age. Global Change Biology 10: 2052-2077. Available online at: http://www3.interscience.wiley.com/cgi-bin/fulltext/118805398/PDFSTART

Reinhardt, E. and L. Holsinger. 2010. Effects of fuel treatments on carbon-disturbance relationships in forests of the northern Rocky Mountains. Forest Ecol. Manage. (2010), doi:10.1016/j.foreco.2010.01.015.

Running, S.W. 2006. Is global warming causing more, larger wildfires? Science 313: 927-928.

Ryan, M.G., D.M. Kashian, E.A.H. Smithwick, W.H. Romme, M.G. Turner, and D.B. Tinker. 2008a. Joint Fire Science Program Project Number: 03-1-1-06. Final Report on Carbon cycling at the landscape scale: the effect of changes in climate and fire frequency on age distribution, stand structure, and net ecosystem production. Unpublished report for BLM Agreement/Task Order Number: 1422RAH03-0041 available online at: http://www.firescience.gov/projects/03-1-1-06/project/03-1-1-06_03-1-1-06_final_report.pdf

Ryan, M.G., S.R. Archer, R. Birdsey, C. Dahm, L. Heath, J. Hicke, D. Hollinger, T. Huxman, G. Okin, R. Oren, J. Randerson, and W. Schlesinger. 2008b. Land Resources. In: The effects of climate change on agriculture, land resources, water resources, and biodiversity in the United States. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. Washington, DC., USA. 362 pp. Available online at: http://www.sap43.ucar.edu/documents/SAP_4.3_6.18.pdf

Ryan M.G., M.E. Harmon, R.A. Birdsey, C.P. Giardina, L.S. Heath, R.A. Houghton, R.B. Jackson, D.C. McKinley, J.F. Morrison, B.C. Murray, D.E. Pataki, and K.E. Skog. 2010. A Synthesis of the Science on Forests and Carbon for U.S. Forests. Issues in Ecology, Report Number 13. 17 p.

Seager, R., M. Ting, Y. Kushnir, J. Lu, G. Vecchi, H. Huang, N. Harnik, A. Leetmaa, N. Lau, C. Li, J. Velez and N.Naik. 2007. Model projections of an imminent transition to a more arid climate in southwestern NorthAmerica. Science 316: 1181-84.

Seager and Vecchi 2010. Greenhouse warming and the 21st century hydroclimate of southwestern North America. Proceedings of the National Academy of Sciences 107(50): 21277-21282.

Savage, M. and J.N. Mast. 2005. How resilient are southwestern ponderosa pine forests after crown fires? Can. J. For. Res. 35: 967–977.

Strom, B.A. and P.Z. Fulé. 2007. Pre-wildfire fuel treatments affect long-term ponderosa pine forest dynamics. International Journal of Wildland Fire 16: 128-138.

Thorne, J., et al. 2018. Climate change vulnerability assessment of forests in the Southwestern USA. Climatic Change 148:387-402.

US EPA 2013. Chapter 7. Land Use, Land-Use Change, and Forestry, in Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2011. The entire report is available online at: http://www.epa.gov/climatechange/ghgemissions/usinventoryreport.html

Wear, D.N. and B.C. Murray. 2004. Federal timber restrictions, interregional spillovers, and the impact on US softwood markets. Journal of Environmental Economics and Management Volume 47, Issue 2, March 2004, Pages 307-330.

Westerling, A.L. and B.P. Bryant. 2008. Climate change and wildfire in California. Climatic Change: 87(Suppl. 1): S231-S249.